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BIOLOGICAL BULLETIN

A SIGNIFICANT CASE OF HERMAPHRODITISM IN FISH.[1]

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The subject of hermaphroditism in fish has received the attention of only a few workers. Our principal information is derived from the work of Stephan ('01). This author describes for certain species of fish a complete and simultaneous hermaphroditism, ripe ova and spermatozoa appearing in the same individual at the same time; for other species a protandric hermaphroditism, the individuals while young being males and later in life becoming females; for still others, a precocious appearance of sexuality in the males and a tardy appearance of the latter in the females of species still considered as unisexual.

The condition last mentioned is interpreted by Roule ('02), on the basis of rather doubtful evidence, as a true case of protandric hermaphroditism. He measured large numbers of sexually mature individuals belonging to several species of Cyprinidæ, and found that all of the individuals of small size were males and all those of large size were females. Hence, according to Roule, all individuals are males when young and females when older. The only alternative interpretation of the facts presented seems to be that these species exhibit strict unisexuality of all individuals, with dwarfing of the males and precocious appearance of male sexuality. Roule points out, however, that, on this basis, one would expect to find among the smaller individuals young females with immature sex glands, and that there should be at least as many of the latter as there are adult females. But none such were found by him.

[1] Contribution from the Zoölogical Laboratory of the University of Texas, No. 94.

Roule's paper, being simply a preliminary statement, is too inadequate to furnish the basis for a detailed discussion, yet it might be well to point out that the Pœciliidæ, a family rather closely related to the Cyprinidæ with which Roule worked and about which there can be no suspicion of normal hermaphroditism, exhibit conditions closely parallel to those cited by Roule.

Let us take, for example, the state of affairs in *Fundulus majalis*. Here the mature males are, on the average, considerably smaller than the mature females; yet the largest of the males often surpass in size the smaller sized females. Again, the very smallest sexually mature individuals are always males and the very largest are always females. The males also mature distinctly earlier in the season than do the females. All of these facts attest the precocity and dwarfing of the males.

In view of the fact, however, that in *F. majalis* there is a very pronounced sexual dimorphism that begins to make itself apparent in very young and immature fish, it becomes certain that all individuals are unisexual throughout life. The individual whose discovery gave occasion for this paper, is the only exception to this rule that has come under the observation of the writer although he has examined thousands of specimens of this and allied species during the last three years.

In order that the reader may more readily understand the account of this rather remarkable case of hermaphroditism it seems necessary to recapitulate certain facts concerning the sexual dimorphism and spawning behavior of *Fundulus majalis*, a subject treated extensively in former papers (Newman, '07 and '08).

In *F. majalis* the sexes differ in the following particulars:

1. The females are larger, on the average, than the males.

2. The body color pattern of the two sexes is entirely different; that of the male consisting of distinct transverse bands running from back of the head to near the base of the caudal fin (see Fig. 1); that of the female, on the other hand, consisting essentially of well-marked longitudinal stripes, perfect anteriorly and merging posteriorly into a few cross bands like those of the male (see Fig. 4).

3. The cross-banded pattern is the primitive one for the family as well as for the species, and all young fish of both sexes start out with this pattern. The males retain this juvenile pattern, in a somewhat strengthened form, throughout adult life. In the females, however, the primitive cross-banded pattern is gradually transformed into one characterized by longitudinal stripes, in the following manner. The cross bands, beginning with the anterior ones, show thickenings in two places. The parts of the bars between these thickened regions thin out and disappear, leaving

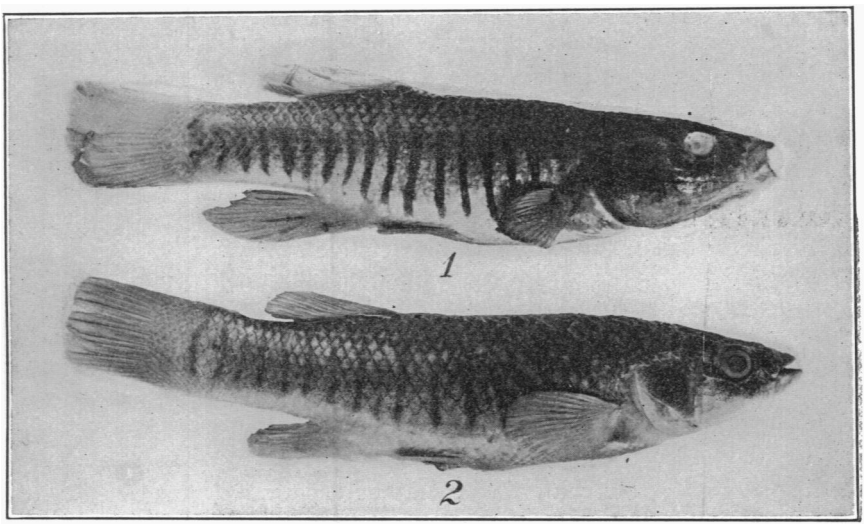


FIG. 1. Photograph of preserved specimen of male *Fundulus majalis* from the right side (slightly reduced). This specimen shows the dark spawning coloration about head and back, the large size of dorsal and anal fins, the typical cross-banded pattern. The characteristic male marking on the dorsal fin, however, shows only faintly.

FIG. 2. Photograph of the hermaphrodite specimen of *F. majalis*, taken with the same exposure as Fig. 1. Note that the general body coloration is almost that of the male, but that the cross-banded pattern is weaker. This pattern, however, was much stronger in life. In other respects it resembles the female (Fig. 4).

the thickened regions arranged in two rows. These then fuse longitudinally into two or more stripes. This process is described fully and figured in a former paper (Newman, '07).

4. The male is characterized by the presence of a very prominent dark spot or series of spots, surrounded by a light area situated on the posterior rays of the dorsal fin. The photograph

(Fig. 1) does not do this character justice. A far better idea of the prominence of this sexual marking can be obtained from an examination of the illustration in the paper just referred to.

5. The dorsal and anal fins of the male are much larger and stronger than those of the female and are used as clasping organs in spawning.

6. These fins and all parts of the body of the male that come into intimate contact with that of the female in spawning and courtship are covered with small finger-like papillæ that lend to these parts a decided roughness and undoubtedly assist the male in holding the female securely. These organs have elsewhere been designated "contact organs."

7. During the sexual climax the whole body of the male is suffused with dark pigment, some specimens showing an almost inky blackness on head, cheeks and back. The female, however, retains her normal pale olivaceous tint, or in many cases becomes distinctly paler than during the vegetative season.

8. The flesh of the female, during the height of the spawning season, becomes softer than usual and the abdomen is greatly distended with ripe ova.

9. The behavior of the males, during the spawning season, is sharply contrasted with that of the females. The former are spirited and pugnacious, and frequently follow the females about in order to spawn with them. Actual spawning, however, was observed only occasionally in *F. majalis*, but it is essentially like that of *F. heteroclitus*, which was observed hundreds of times. The behavior of the female is characteristically coy.

These and a few minor differences between the sexes will serve to render intelligible the account of the individual now to be described.

Description of the Hermaphrodite Specimen.

The fish herein described was discovered by merest chance during the progress of some breeding experiments at the Woods Hole laboratories.

On July 3, 1907, needing a male *Fundulus majalis*, I rather hurriedly dipped out of the aquarium what I took to be a large, but decidedly pale, male. Wishing to perform an experiment

with the milt of just such a male as this seemed to be, I attempted, without further examination, to strip milt from the specimen. Instead of milt a stream of eggs issued from the short genital tube at the base of the anal fin. I knew, of course, that fish frequently eat eggs and pass them undigested through the digestive tract, but such eggs are always dead and opaque, while these eggs were normally transparent. Surprised at the extrusion of eggs from an individual supposedly male I proceeded to make a careful examination. This revealed the fact that the fish was male only in one respect. It showed the cross-banded body pattern of the male very distinctly. It lacked, however, the characteristic spot on the dorsal fin, the large size of dorsal and anal fins, contact organs, and intensified pigment of the typical male; while it possessed the distended abdomen soft flesh, lighter ground color, small fins, and external oviducal tube of the spawning female. Yet I had never before seen an adult or even a juvenile female without longitudinal stripes distinctly indicated.

The specimen seemed sufficiently unusual to deserve a separate aquarium, where it was well fed and relieved of its burden of eggs several times during the ensuing fortnight. These eggs showed a rather low degree of fertility, although at least ten per cent. developed in each case.

After about a week a typically marked female of about the same size was introduced into the special aquarium for the sake of comparison, and both normal and abnormal specimens were treated alike. For nearly two weeks the two fish behaved alike, but after that time the cross-banded fish began to lose its quiet passive behavior and to assume a decidedly overbearing attitude toward its companion. Several of my fellow investigators called my attention to this curious behavior, which might well be termed "bossy." Accompanying this change in behavior were several morphological changes. The body became slimmer, as would be expected since the eggs had practically all been extruded, the flesh became harder, and dark pigment was laid down all over the body. The latter was most noticeable on head and cheeks which had become decidedly dusky, a change very characteristic of males entering upon the period of high sexual tone. The cross bands become darker and more distinct and a faint wash of orange tint appeared on the anal fin, a distinctly male character.

During the last week of July the fish was kept under close observation. On several occasions it showed a type of behavior distinctly male-like. It followed the female about and repeatedly made movements that seemed to indicate a weak attempt at spawning. Of this I could not be positive, but in other respects the behavior was that of a courting male. It would have surprised me greatly had there been an exhibition of actual spawning, for, as has been said, *F. majalis* seldom spawns in captivity.

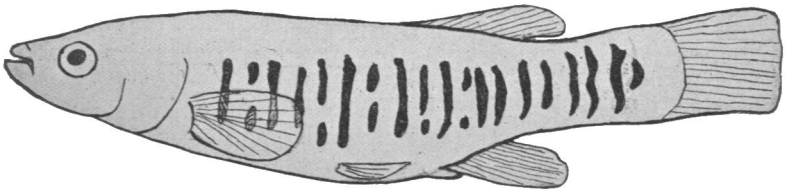
On the last day of July the writer was compelled to leave the laboratories and the fish was killed and carefully preserved in formalin.

An examination of the formalin-preserved sex gland revealed the fact that it was a composite gland, containing about five per cent. of testicular tissue, slightly immature, and imbedded in a mass of immature and stale ovarian tissue. The testicular tissue occurred in minute lumps, principally near the posterior end of the gland. Although distinctly testicular in structure, these small masses showed a less typical structure than that of normal testis, being less compact and interspersed with connective tissue. The color, size and general appearance of the whole gland was that of a preserved testis, there being no yellow color present as is the case in normal ovaries after the close of the spawning season.

A further close examination of the body pattern showed that the cross banding on right and left sides was not equally perfect, that of the right side showing the character in as perfect a form, if less distinct, as in a typical male, that of the left being partially broken into shorter bars, the beginning of a tendency on the part of the cross-banded pattern to break up into the rows of spots that furnish the material for longitudinal stripes.

The photograph of the specimen taken from the right side shows the pattern far less distinctly than in life on account of the fact that scales and skin, rendered opaque by the preservative, obscure the underlying markings. In other respects the illustration (Fig. 2) is a faithful representation of the conditions. Photographs of the left side failed entirely to bring out the points desired, so it was necessary to insert a camera drawing as the best substitute. This drawing (Fig. 3), showing the less perfect

cross banding, when compared with the average condition seen in an adult female (Fig. 4), will show a striking contrast. It will be noted that the hermaphrodite exhibits a somewhat juvenile figure in that the head is shorter, the body broader and the tail less tapering. These points might not be patent to one not very familiar with the species.



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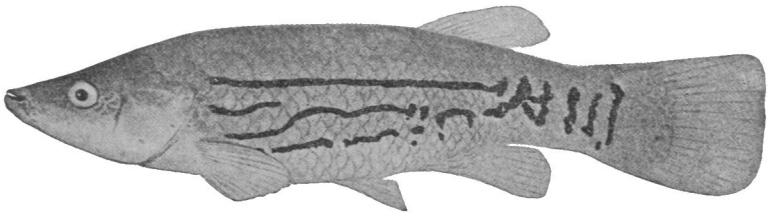

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FIG. 3. Outline camera drawing of the hermaphrodite from the left side, to show the rather broken character of the cross-banded pattern.

FIG. 4. Wash drawing, showing a typical female *F. majalis*. Many specimens show a far more complete transformation of the juvenile cross-banded pattern into the series of longitudinal stripes but few females of this size show a less advanced condition. Note the long head, comparatively small dorsal and anal fins, and comparatively light ground color of head and back.

GENERAL CONSIDERATIONS.

1. The extreme rarity of hermaphroditism in fish normally unisexual makes this case worthy of note, especially as the sexes are so well differentiated in form, color pattern, and behavior. No other case comparable with this is on record. There seems, in fact to be only one case of abnormal hermaphroditism in fish in the available literature. This is a brief description by Southwell ('02), of a hermaphrodite gland taken from a smoked her-

ring. The only point of interest for this discussion, since herrings seem to show no sexual dimorphism, is that the testicular tissue was located posterior to the ovarian tissue and overlapped the latter somewhat. This condition of the sex glands reminds one of the composite gland described in the preceding paragraphs.

2. Some light is thrown on the influence of the sexual secretions upon the secondary sexual characters. In this case the presence of a comparatively minute amount of imperfect testicular tissue has had the negative effect of inhibiting, in an individual predominantly female, the transformation of the juvenile into the female color pattern ; and the positive effect of producing in this individual, at the expiration of the season's period of egg production, an approximation of male coloration and behavior.

3. In all cases of serial hermaphroditism described in available literature the hermaphroditism is protandric and in successive seasons. Here the sequence was distinctly protogynic and the changes occurred within a period of less than a month. The condition is decidedly anomalous.

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